

CHAPTER 2

RELIABILITY

Reliability is a term used to describe quantitatively how failure-free a system is likely to be during a given period of operation. The ability to express reliability numerically is crucial, because it enables us to concretely identify the user's needs, contractual specifications, test guidelines and performance assessment.

DEFINITION OF TERMS AND CONCEPTS

Reliability

Reliability is defined as the probability that an item will perform its intended function for a specified interval under stated conditions. This definition does not specifically consider the effect of the age of the system.

The following adaptation is useful for systems that are repairable. Reliability, for repairable systems, is the probability that an item will perform its intended function for a specified interval, under stated conditions, at a given age, if both corrective and preventive maintenance are performed in a specified manner.

If a system is capable of performing multiple missions, or if it can perform one or more of its missions while operating in a degraded condition or if the mission test profiles represent only typical usage, then, the concept of a **unique mission reliability becomes difficult to define. In such cases**, it is preferable to use a reliability measure that is not based solely on the length of a specified time interval but rather on the definition of a specific mission profile or set of profiles. This concept is illustrated in Case Study 2-7.

The meaning of the terms "**stated** conditions" and "specified interval" are important to the understanding of reliability. The term "**stated** conditions" refers to the complete definition of the scenario in which the system will operate. For a ground combat vehicle, these conditions include climatic conditions, road surface, and **loads** that would be experienced during a selected mission profile. These conditions should reflect operational usage. The term "specified interval" refers to the length of the mission described in a mission profile. This interval may include multiple factors. For example, an air defense system mission profile **will** define an interval containing X rounds fired, Y hours of electronics on-time and Z miles of travel. For a simpler system, say an air-burst artillery round, the interval may include a single event--round detonation.

Mean Time Between Failures

Mean time between failures (MTBF) is defined as the total functioning life of a population of an item during a specific measurement interval, divided by the total number of failures within the population during that interval. MTBF can be interpreted as the expected **length** of time a system will be operational

between failures. The definition is true for time, cycles, miles, events, or other measure-of-life units. These various measure-of-life units permit the MTBF term to be tailored to the reliability requirements of a specific system. Some examples of this tailoring are:

- Mean rounds between failure (MRBF)
- Mean miles between operational mission failure (MMBOMF)
- Mean time between unscheduled maintenance actions (MTBUMA)
- Mean rounds between any maintenance actions (MRBAMA)

Failure Rate

Failure rate is defined as the number of failures of an item per **measure-of-life** unit (e.g., cycles, time, miles or events as applicable). This measure is more difficult to visualize from an operational standpoint than the MTBF measure, but is a useful mathematical **term** which frequently appears in many engineering and statistical calculations. As we will see in later chapters the failure rate is the reciprocal of the MTBF measure, or

$$\text{Failure Rate} = \frac{1}{\text{MTBF}}$$

SYSTEM RELIABILITY DESIGN OBJECTIVES

There are two very different system reliability design objectives. One is to enhance system effectiveness; the other is to minimize the burden of owning and operating the system. The first objective is addressed by means of mission reliability, the second by means of logistics-related reliability. Measures of mission reliability address only those incidents that affect mission accomplishment. Measures of logistics-related reliability address all incidents that require a response from the logistics system.

Mission Reliability

Mission reliability is the probability that a system will perform mission essential functions for a period of time under the conditions stated in the mission profile. Mission reliability for a single shot type of system, i.e., a pyrotechnic device, would not include a time period constraint. A system with a high mission reliability has a high probability of successfully completing the defined mission.

Measures of mission reliability address only those incidents that affect mission accomplishment. A mission reliability analysis must, therefore, include the definition of mission essential functions. For example, the mission essential functions for a tank might be to move, shoot and communicate. More specific requirements could specify minimum speed, shooting accuracy and communication range'.

See Case Study 2-7.

Logistics (Maintenance/Supply) Related Reliability

Logistics related reliability measures, as indicated above, **must** be selected **so** that they account for or address **all** incidents that require a response from the logistics system.

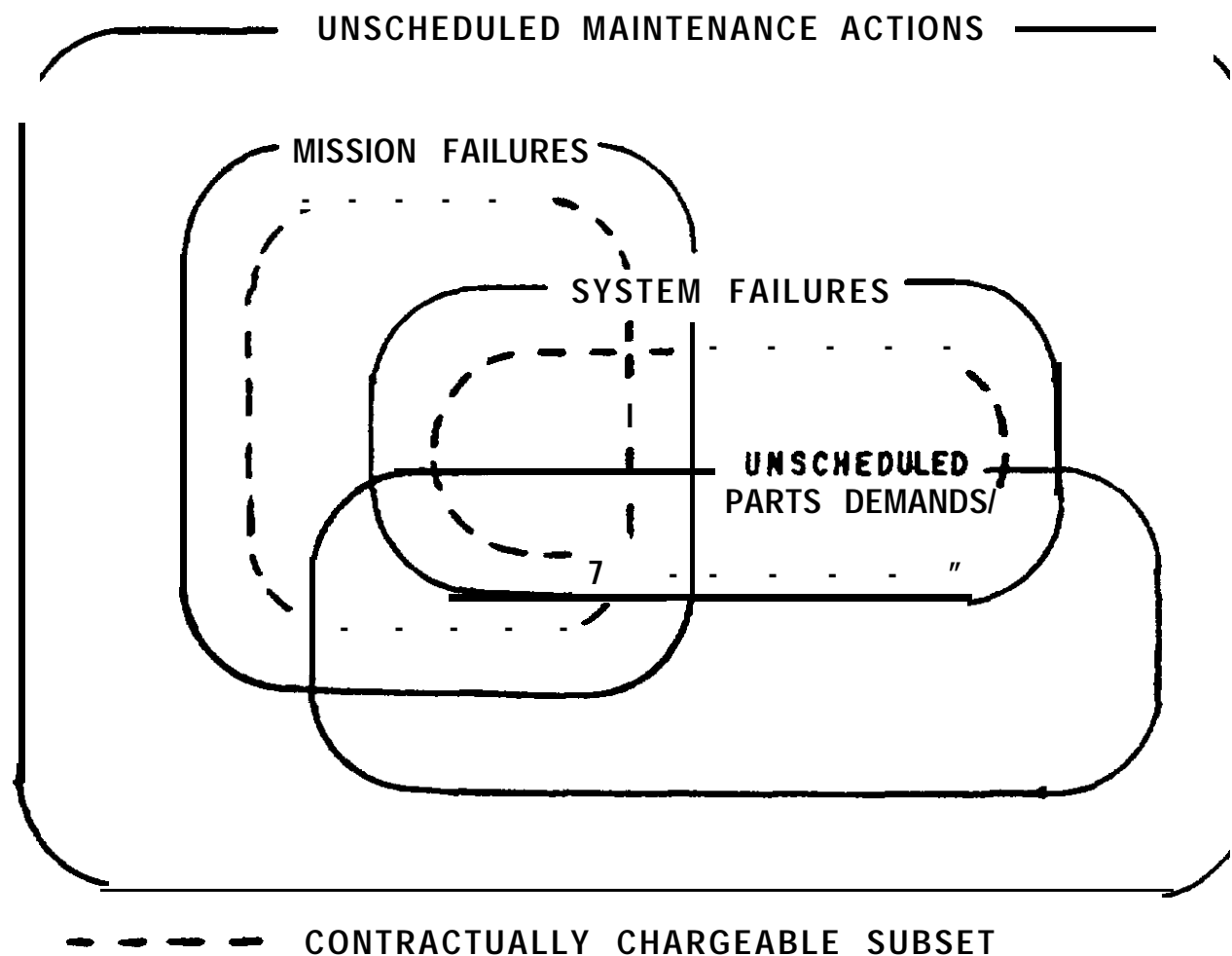
Logistics related reliability may be further subdivided into maintenance related reliability and supply related reliability. These parameters respectively represent the probability that no corrective maintenance or the probability that no unscheduled supply demand will occur following the completion of a specific mission profile.

The mathematical models used to evaluate mission and logistics reliability for the same system may be entirely different. This is illustrated in Case Study 2-3.

RELIABILITY INCIDENT CLASSIFICATION

An understanding of the relationships existing between the above reliability measures and other terms is essential to the knowledgeable application of these parameters. Figure 2-1 illustrates the effects of these relationships not their causes. For example, system failures may be caused by the hardware itself, by the operator, or by inadequate/faulty maintenance.

FIGURE 2-1 RELIABILITY INCIDENT CLASSIFICATION



Mission Failures

Mission failures are the loss of any of the mission's essential functions. Along with system hardware failures, operator errors and errors in publications that cause such a loss are included in this region. Mission failures

are related to mission reliability measures because they prevent complete mission accomplishment.

System Failures

System failures are hardware malfunctions: they may or may not affect the mission's essential functions, and they may or may not require spares for correction. A system failure generally requires unscheduled maintenance so system failures heavily influence maintenance-related reliability.

Unscheduled Spares Demands

Unscheduled spares demands are used to evaluate supply-related reliability. All unscheduled spares demands require a response from the supply system, so they form the basis for evaluating supply-related reliability.

System/Mission Failures Requiring Spares

System/mission failures that require spares for correction are the most critical. Mission, maintenance and supply reliabilities are affected, and the system runs the risk of being held in a non-mission-ready status for an extended period of time by logistics delays.

Contractually Chargeable Failures

Contract requirements are often established for the subset of mission failures and/or system failures for which the contractor can be held accountable. Normally excluded from contractual chargeability are such **failure** categories as: operator or maintenance errors; item abuse; secondary failures caused by another (primary) failure; and failures for which a "fix" has been identified (but not incorporated in the test article that failed). It should be noted that, in operation, all failures (in fact, all unscheduled maintenance actions) are relevant regardless of contractual chargeability, and should therefore be included in operational evaluations.

SYSTEM RELIABILITY MODELS

System reliability models are utilized to describe visually and mathematically the relationship between system components and their effect on the resulting system reliability. A reliability block diagram or structural model provides the visual representation while the mathematical or "math" model provides the analytical tool to calculate quantitative reliability values.

The following notation is used in the discussion of reliability models:

R_s = reliability of the system

R_i = reliability of the i^{th} subsystem

$Q_s = 1 - R_s$ = unreliability of the system

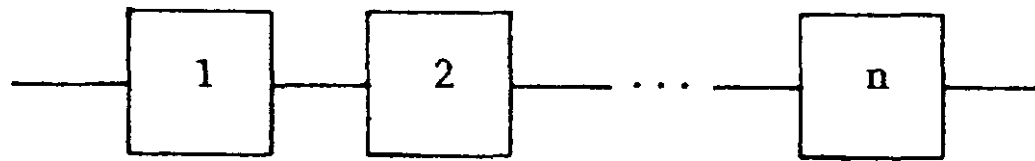
$Q_i = 1 - R_i$ = unreliability of the i^{th} subsystem

Π = product of (Note: This operator is used in the same fashion as Σ for summation, but it indicates multiplication rather than addition.)

Note: In the following discussion it is assumed that all subsystems function independently of one another, that is, failures of different subsystems are statistically independent of each other. For many systems this represents a realistic assumption. The reliability analysis for dependent subsystems is significantly more complex. Independent operation, practically speaking, means that a failure of one system **will** not cause a change in the failure characteristics of one or more other subsystems. Therefore, replacement of the single failed subsystem should permit continued operation of the entire system, because other subsystems were not affected.

Series Model

When a group of components or subsystems is such that all must function properly for the system to succeed, they are said to be in series. A system consisting of a series arrangement of n subsystems is illustrated in the following block diagram:



The mathematical model is

$$R_s = R_1 R_2 \dots R_n = \prod_{i=1}^n R_i. \quad (2.1)$$

See Case Studies 2-1, 2-2, 2-3, 2-5, and 2-6 for examples of reliability series models.

Redundant Models

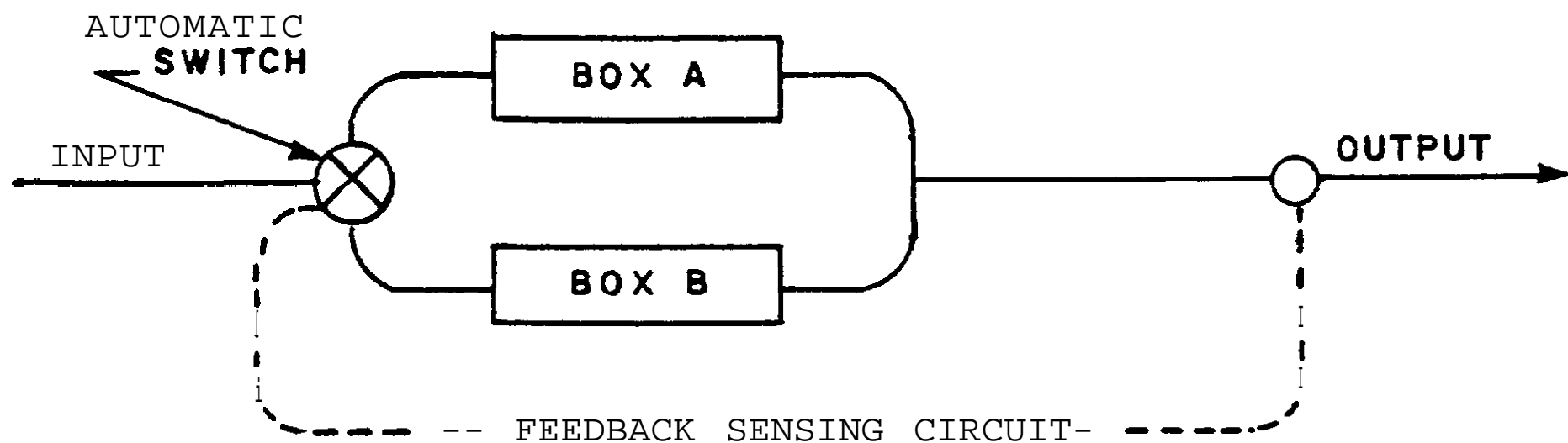
The mission reliability of a system containing independent subsystems can usually be increased by using subsystems in a redundant fashion, that is, providing more subsystems than are absolutely necessary for satisfactory performance. The incorporation of redundancy into a system design and the subsequent analysis and assessment of that design is a complex task and will not be addressed here in detail. We will define the elements of redundancy and present several simplified examples.

Redundance Characteristics. Redundance can be defined by three basic characteristics.

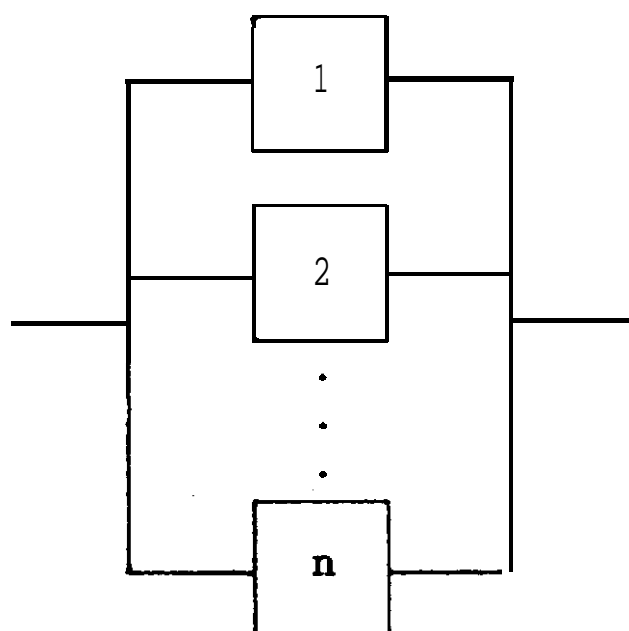
- First, the level at which redundancy is applied. For example, we could have redundant pieceparts, redundant black boxes, or **complete** redundant systems.

- Second, the operating state of the redundant element. The redundant part, subsystem, etc., may exist in the circuit as an active functioning element or as a passive, power off, element. For example, an airport that maintains two separate operating ground control approach radars at all times has active redundancy for that capability. Carrying a spare tire in your trunk is an example of passive redundancy.
- Third, the method used to activate the redundant element. Consider the passive redundancy case of the spare tire. The vehicle driver represents the switching device that decides to activate the spare. Obviously mission time is lost in installing the spare. The opposite case is represented by the use of an electronic switching network that senses the failure of Box A and automatically switches to Box B without lost time or mission interruption.

FIGURE 2-2 PASSIVE REDUNDANCY WITH AUTOMATIC SWITCHING



Our examples will consider only simple active redundancy. In this type of redundancy, all the operable subsystems are operating, but only one is needed for satisfactory performance. There are no standby subsystems, and no repair is permitted during the mission. Such a system of n subsystems is illustrated in block diagram form as:



Note: Simple active redundancy requires that only one of the n subsystems be **operating** for mission success.

The mathematical model is

$$Q_s = Q_1 Q_2 \dots Q_n = \prod_{i=1}^n Q_i = \prod_{i=1}^n (1 - R_i).$$

$$R_s = 1 - Q_s = 1 - \prod_{i=1}^n (1 - R_i). \quad (2.2)$$

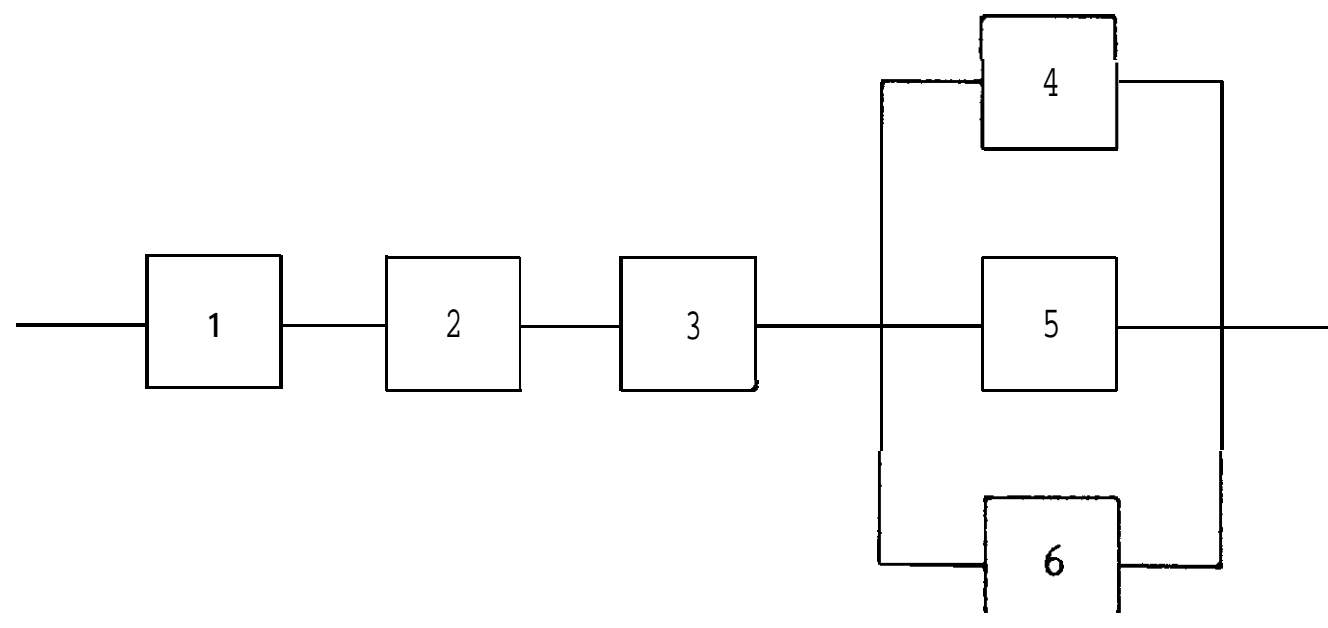
This model again assumes that there is statistical independence among failures of the subsystems. This assumption is important because dependence between subsystems can have a significant effect on system reliability. Calculations based on an assumption of independence can be erroneous and misleading. In fact, erroneously assuming failure independence will often result in overestimating system reliability for an active redundant system and underestimating reliability for a series system.

Implications of Redundant Design. While redundant design does improve mission reliability, its use must be weighed against the inherent disadvantages. These disadvantages include greater initial cost, increased system size and weight, increased maintenance burden and higher spares demand rates. These factors must be considered by using and procuring agencies and by testing organizations when assessing the true mission capability and support requirements.

Although there are some possible exceptions, redundancy generally improves mission reliability and degrades logistics reliability. Case Study 2-3 gives a numerical comparison between mission- and maintenance-related reliability.

Mixed Models

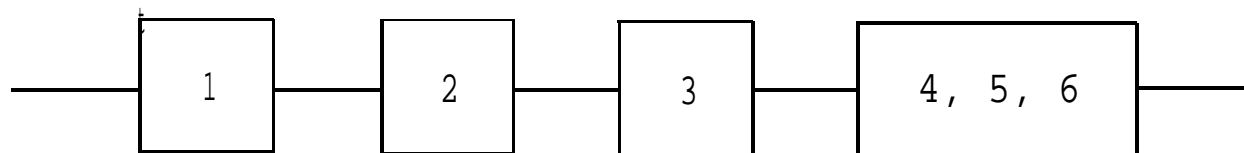
One system configuration that is often encountered is one in which subsystems are in series, but redundancy (active) is applied to a certain critical subsystem(s). A typical block diagram follows:



This type of model (or any mixed model, for that matter) is characterized by working from low to high levels of assembly. In this case, assuming independence and active redundancy, we can apply equation 2.2.

$$R_{4,5,6} = 1 - (1 - R_4)(1 - R_5)(1 - R_6) \quad (2.3)$$

We can now represent the redundant configuration of 4, 5, and 6 by a single block on the diagram.



We can now apply equation 2.1:

$$R_s = R_1 R_2 R_3 R_{4,5,6}$$

$$R_s = R_1 R_2 R_3 [1 - (1 - R_4)(1 - R_5)(1 - R_6)] \quad (2.4)$$

See Case Study 2-4 for the numerical analysis of a mixed model.

Functional Models

The series, redundant and mixed models mentioned above, are hardware-oriented in that they display hardware capabilities. In some cases, it is desirable to model a system from a functional standpoint. As an example, the functional reliability block diagram for a tank is shown below:



The functions may be defined as:

- MOVE. The mobility system must be capable of effectively maneuvering such that the system can maintain its assigned position within a tactical scenario. Specific requirements are determined for speed, turning, terrain, etc.
- SHOOT. The main gun must be capable of delivering effective fire at the rate of X rounds per minute.
- COMMUNICATE. The communication system must be capable of providing two-way communication with other vehicles and with fixed stations within specific ranges and terrain confines.

Note that this concept addresses mission-essential functions, but in no way implies how these functions will be accomplished. Generally the functional

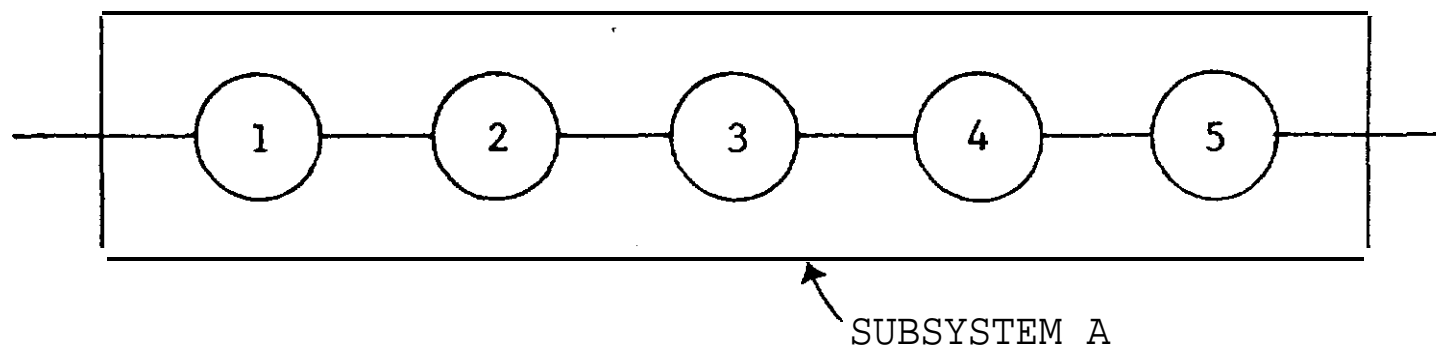
model approach is helpful in the program formulation stages of a program when specific hardware information is not necessary and frequently not desired. This type of model can provide a useful transition from operational requirement to engineering specifications.

Case Study 2-7 utilizes this concept to evaluate the multi-mission, multi-mode capabilities of a system.

BELIABILITY ALLOCATION

The previous section presented the topic of functional reliability models and indicated that these models provided a useful means of transitioning from operational requirements to engineering specifications. The process of **trans-**itioning from operational requirements to engineering specifications is known as reliability allocation. The reliability allocation process "allocates" the reliability "budget" for a given system or subsystem to the individual components of that system or subsystem. An example will prove helpful.

Suppose we have previously determined that the reliability of an electronic subsystem A, must equal or exceed 0.90, and that this subsystem has been designed with 5 parts all functioning in series. For this example, we will assume Parts 1, 2 and 3 are the same and the best available piece part for Part 4 has a reliability of 0.990. How can we allocate the reliability budget for this subsystem to its individual parts?



Using equation 2.1 we have

$$R_{\text{Total}} = R_1 R_2 R_3 R_4 R_5$$

$$= R_1 R_2 R_3 (0.990) R_5$$

Solving for $R_1 R_2 R_3 R_5$ we have

$$R_1 R_2 R_3 R_5 = \frac{0.900}{0.990} = 0.909$$

If we assume $R_1 = R_2 = R_3 = R_5$ then,

$$R_1 = R_2 = R_3 = R_5 = \sqrt[4]{0.909} = 0.976$$

If we can locate piece parts for Part 5 with $R_5 = 0.985$, then

$$R_1 R_2 R_3 = \frac{0.909}{R_5} = \frac{0.909}{0.985} = 0.923. \text{ So,}$$

$$R_1 = R_2 = R_3 = \sqrt[3]{0.923} = 0.973.$$

Summary of Allocation

<u>Case I</u>	<u>Case II</u>
$R_1 = R_2 = R_3 = R_5 = 0.976$	$R_1 = R_2 = R_3 = 0.973$
$R_4 = 0.990$	$R_4 = 0.990$
	$R_5 = 0.985$

Another, and somewhat more frequently used approach to reliability allocation is one in which reliability is allocated on the basis of allowable failures or failure rates.

The understanding of reliability allocation is important to those individuals who must be concerned with hardware operating characteristics **below** the system level. This is especially true to development and testing organizations who are frequently faced with predicting system performance early in development, when no full-up system exists but when subsystem or component test data may be available.

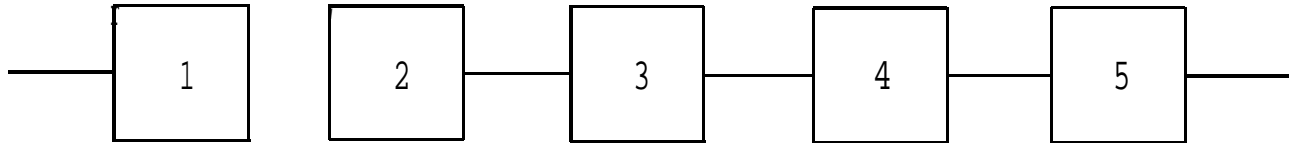
See Case Study 2-5 for another example of reliability allocation.

CASE STUDY NO. 2-1

Background

A system is composed of 5 subsystems, each of which must succeed for system success. Past records indicate the subsystem reliabilities to be as shown on the diagram.

$$R_1 = 0.9 \quad R_2 = 0.95 \quad R_3 = 0.99 \quad R_4 = 0.99 \quad R_5 = 0.9$$



Determine

System reliability.

Solution

Applying equation 2.1:

$$R_S = R_1 R_2 R_3 R_4 R_5 = (0.9)(0.95)(0.99)(0.99)(0.9) = 0.75$$

Commentary

Note that the system reliability is lower than that of the worst subsystem. This is generally the case for a series structured system.

CASE STUDY NO. 2-2

Background

An electronic system has 1000 components in reliability series. The reliability of each component is 0.999.

Determine

System reliability.

Solution

Applying equation 2.1:

$$R_s = \prod_{i=1}^{1000} 0.999 = (0.999)^{1000} \cong 0.368$$

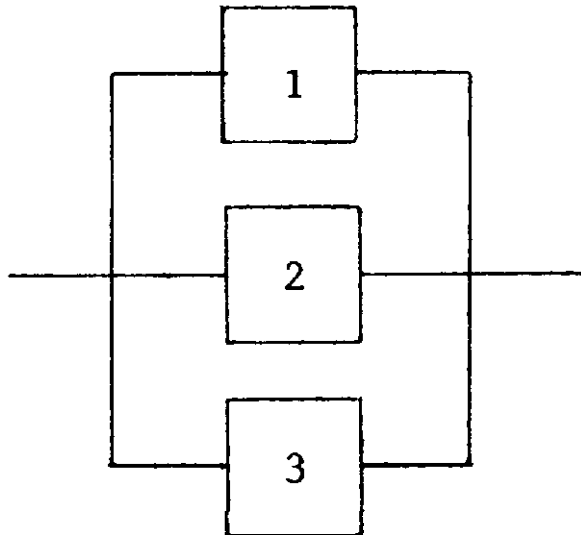
Commentary

1. Even though a component reliability of 0.999 sounds good, the sheer number of these components causes a low system reliability.
2. Even though $0.999 \cong 1.0$, the difference is crucial. For high reliability values, the probability of failure often gives a clearer picture. **For** example, increasing the component reliability from 0.999 to 0.9999 requires a ten-fold reduction of the failure probability.
3. Problems such as this, involving large powers, are solved effortlessly with an electronic calculator with a power capability. The more traditional approach is, of course, the use of logarithms and anti-logarithm tables.

CASE STUDY NO. 2-3

Background

The mission reliability of the system is described by the following block diagram. All subsystems are identical and each has a reliability of $R = 0.90$. No repairs are possible during a mission, but will be made following missions in which failures occur. Failures occur independently. For this case, we assume that any mission failure will require an unscheduled maintenance action.



Determine

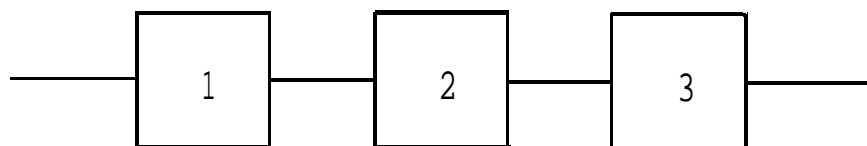
System mission reliability and maintenance reliability (probability of no corrective maintenance following a mission).

Solution

System mission reliability: Applying equation 2.2:

$$R_s = 1 - (1 - R)^n = 1 - (1 - 0.9)^3 = 1 - (0.1)^3 = 1 - 0.001 = 0.999$$

Maintenance reliability: An unscheduled maintenance action required by any subsystem is chargeable to the maintenance burden of the entire system, i.e., a failure, defined in this case to be a requirement for corrective maintenance of one subsystem, is charged as a system failure. As a consequence, we model maintenance reliability for this system using a series structure.



Applying equation 2.1:

$$R_s = R^n = (0.9)^3 = 0.729$$

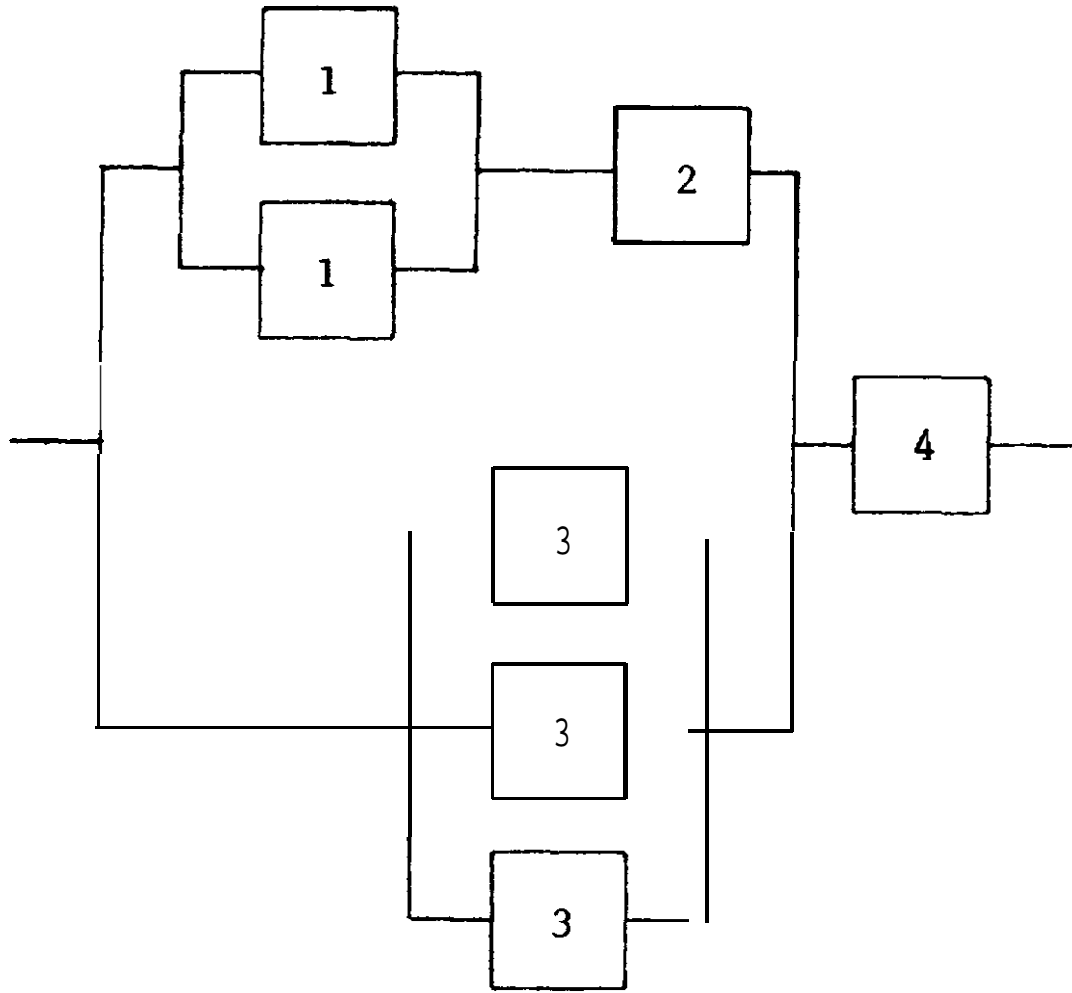
Commentary

1. Note that we evaluated system mission reliability; that is, the reliability of the hardware alone.
2. Based on the given information, it is apparent that a system consisting of only one of the above subsystems **will** have a probability of mission failure equal to 0.1 and a probability of corrective maintenance action also equal to 0.1. The system with triple active redundancy has a mission reliability of 0.999, which corresponds to a probability of mission failure equal to 0.001 (a 100-fold reduction). The same system has a maintenance reliability of 0.729 which corresponds to a probability **of** corrective maintenance action **equal to 0.271** (approximately a **3-fold** increase). The procuring and using agencies must decide whether to contract for redundancy and how much to require based on consideration of these parameters.
3. Note that with active redundancy the system reliability is generally greater than the reliability of the best subsystem.
4. For this example, we stipulated that any mission failure would require an unscheduled maintenance action. The reader should note that this is not always the case.
5. It is possible, for example, to experience the failure of one of two redundant mission critical subsystems and **still** successfully complete the mission. After successful mission completion, an unscheduled maintenance action would **be** necessary to repair/replace the defective critical redundant subsystem.

CASE STUDY NO. 2-4

Background

Consider the following block diagram. Components with the same number are identical and consequently have the same reliability.



$$R_1 = 0.80$$

$$R_2 = 0.95$$

$$R_3 = 0.70$$

$$R_4 = 0.90$$

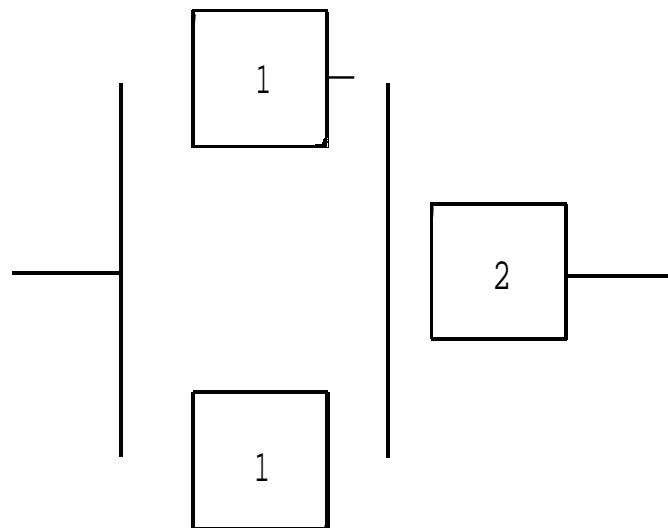
Determine

System reliability assuming independence and active redundancy.

Solution

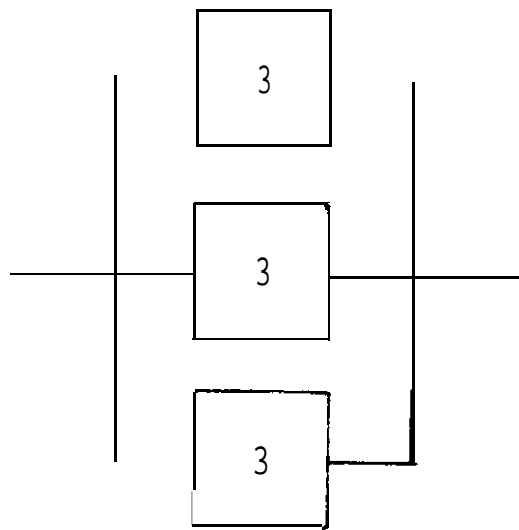
Break the system into subsystems and find the reliability for each using equations 2.1 and 2.2 and then combine into a system model. Define:

Subsystem I as



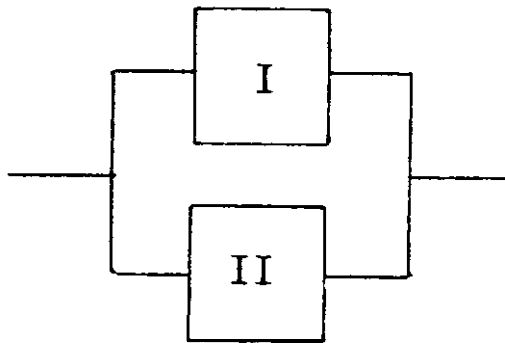
$$R_I = [1 - (1 - R_1)^2] R_2$$

Subsystem II as



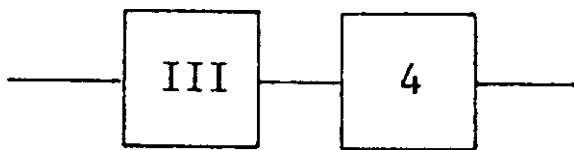
$$R_{II} = 1 - (1 - R_3)^3$$

Subsystem III as



$$R_{III} = 1 - (1 - R_I)(1 - R_{II}) = 1 - \{1 - [1 - (1 - R_1)^2]R_2\}(1 - R_3)^3$$

Then the system becomes



$$R_s = R_4 * R_{III} = R_4 \{1 - \{1 - [1 - (1 - R_1)^2]R_2\}(1 - R_3)^3\}$$

$$= 0.90 \{1 - \{1 - [1 - (1 - 0.80)^2] (0.95) \} (1 - 0.70)^3\} = 0.879$$

Commentary

The general mathematical model is often of more use than the numerical solution, since it permits evaluating a variety of alternatives.

CASE STUDY NO. 2-5

Background

An air defense system comprises a weapon subsystem, a vehicle subsystem and a fire control subsystem. One of the mission profiles for the total system requires firing 250 rounds, traveling 10 miles, and operating the fire control system for 15 hours. The respective subsystem reliabilities for this mission profile are:

$$R_{WE} = 0.95$$

$$R_{VE} = 0.99$$

$$R_{FC} = 0.90$$

Determine

The system is to have its reliability improved by redesign of the fire control subsystem. What reliability is required of this subsystem to attain a system reliability of 0.90?

Solution

This is a series system, so equation 2.1 is applied:

$$R_S = R_{WE} R_{VE} R_{FC}$$

Using stars to represent requirements:

$$R_{FC}^* = \frac{R_S^*}{R_{WE} R_{VE}} = \frac{0.90}{(0.95)(0.99)} = 0.957$$

Commentary

This represents a very simple form of reliability apportionment; that is, allocating a system-level requirement among lower levels of assembly.

Determine

What reliability is required of the fire control system to attain a system reliability of 0.95?

$$R_{FC}^* = \frac{R_S^*}{R_{WE} R_{VE}} = \frac{0.95}{(0.95)(0.99)} = 1.01$$

Since reliability cannot exceed one, the requirement cannot be met. At the very best, $R_{FC} = 1.0$, which would yield:

$$R_S = R_{WE} R_{VE} R_{FC} = (0.95)(0.99)(1.0) = 0.9405$$

Commentary

The "you can't get there from here" solution points out that more than just the fire control system must be improved if a reliability of 0.95 is to be attained.

CASE STUDY NO. 2-6

Background

An electronic system currently in use has approximately 1000 series **components**. The reliability for a 24-hour mission is 0.95. A proposed system will utilize approximately 2000 similar components in series. Assume a similarity in design practices, quality of manufacture, and use conditions.

Determine

1. What is the average part reliability for the current system?
2. What reliability should be expected of the proposed system for a 24-hour mission?

Solution 1

The "average" component reliability can be found by applying equation 2.1 to the old system:

$$R_S = (R_i)^{1000} = 0.95$$

$$R_i = (0.95)^{0.001} = 0.9999487$$

For the new system:

$$R_S = (0.9999487)^{2000} = 0.9025$$

Solution 2

The new system is the reliability equivalent of two of the old systems used in reliability series. Applying equation 2.1:

$$R_S = (0.95)(0.95) = (0.95)^2 = 0.9025$$

Commentary

This type of prediction based on parts count is particularly useful for evaluating feasibility.

CASE STUDY NO. 2-7

Background

A design for a new long-range ocean reconnaissance/weapons control system has been proposed. The system will be used aboard an aircraft whose reliability is not considered in this evaluation. The system has been designed to accomplish six specific missions.

These missions are defined in the table below. Due to size, weight and power limitations, the hardware elements peculiar to each mission must be combined with hardware elements peculiar to other missions in order to form a complete mission hardware set.

For example, as depicted in the table below, the mission hardware set to accomplish Mission E is a combination of hardware elements 3, 4, and 5.

<u>Mission</u>	<u>Mission Description</u>	<u>Mission Hardware Set</u>
A	Long-Range A/C Surveillance	1
B	Long/Short-Range Surface Ship Detection	1,2
c	Area Sea State Information	1,3
D	Subsurface Surveillance	1,3,4
E	Long-Range Terminal Guidance of Ship Launched Missiles	3,4,5
F	Wide Area Weather Data	1,2,3,6

Mission-Peculiar Subsystem Reliabilities

Hardware Element:	1	2	3	4	5	6
Hardware Element Reliability:	95%	93%	99%	91%	90%	95%

All missions are three hours in length and require the operation of all elements in the hardware set for the full three hours.

The mission-peculiar hardware can support several missions simultaneously.

Determine

1. What is the probability of successfully completing each of the six missions?
2. What is the probability of successfully completing all six missions during a three-hour period?

Solution

1. Since the elements function in a series relationship, the individual reliabilities are multiplied. Hence,

$$R_A = R_1 = 0.95$$

$$R_B = R_1 \times R_2 = 0.95 \times 0.93 = 0.88$$

$$R_C = R_1 \times R_3 = 0.95 \times 0.99 = 0.94$$

$$R_D = R_1 \times R_3 \times R_4 = 0.95 \times 0.99 \times 0.91 = 0.85$$

$$R_E = R_3 \times R_4 \times R_5 = 0.99 \times 0.91 \times 0.90 = 0.81$$

$$R_F = R_1 \times R_2 \times R_3 \times R_6 = 0.95 \times 0.93 \times 0.99 \times 0.95 = 0.83$$

2. The probability of successfully completing all six missions during a single three-hour period is determined by multiplying together the individual hardware element reliabilities. This is done because all individual hardware elements must function throughout the three-hour period to enable **all** missions to be completed successfully.

Note that the probability of completing **all** six missions successfully is not correctly calculated by multiplying together the individual **mission** reliabilities R_A through R_F . This approach would erroneously take individual hardware element reliability into account more than once.

$P_{\text{Total Mission}}$ = Probability of successfully completing six missions during a three-hour period

$$P_{\text{Total Mission}} = R_1 \times R_2 \times R_3 \times R_4 \times R_5 \times R_6$$

$$= 0.95 \times 0.93 \times 0.99 \times 0.91 \times 0.90 \times 0.95$$

$$= 0.68$$

Commentary

The significant point illustrated by this problem is that the reliability of multi-mission/multi-mode systems should be presented in terms of their individual mission reliabilities. This is a useful technique because it permits us to evaluate a system's development progress relative to its individual capabilities rather than its total mission reliability which may prove less meaningful. For example, if we assume that Missions A and B are the primary missions, we see that the system has an **88%** chance of successfully completing both functions during a three-hour period. However, if we evaluate Missions A and B along with the remaining four lower-priority missions, we find that our analysis of the total system capability is far different, i.e., 68% chance of

success. Consequently, for this case, approval to proceed with system development would likely be given based on the criticality of Missions A and B and the relatively good probability of successfully completing Missions A and B.

In summary, for multi-mission/multi-mode systems, the presentation of individual *mission* **reliabilities** provides a more meaningful picture of a system's development status and its current and projected combat capabilities as these relate to primary mission achievement.

NOTE : If the individual mission completion times had not been equally constrained to the three-hour time period, we would have been required to use the more sophisticated techniques presented in Chapter 5.